Macrophysiology as a powerful tool for evaluating metapopulation stress and the effectiveness of conservation actions

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Currently shy of 7.6 billion people globally, and with an increase of over 4 billion souls in the 20th century alone, the human population and related anthropogenic activities are putting tremendous pressure on natural, once pristine, ecosystems (Sanderson et al., 2002). Overexploitation, alteration and loss of habitat, species introduction, climate change and pollution have reduced the historical distribution ranges of many species to a few relict populations, or led to local extinctions, with major losses of functional and genetic diversity (Dixo, Metzger, Morgante, & Zamudio, 2009; Estes et al., 2011; Keller & Largiader, 2003). According to the IUCN Red List of Threatened Species, 86%–88% percent of all threatened birds, mammals and amphibians assessed in 2010 were somehow threatened by habitat alteration and/or loss (IUCN, 2017). Faced with such sobering facts, conservation actions worldwide have implemented protected areas in numerous terrestrial, marine and freshwater ecosystems to prevent (and hopefully reverse) current rates of biodiversity loss (Chape, Harrison, Spalding, & Lysenko, 2005).

The establishment of protected areas, however, poses several critical questions. From a societal perspective, protected areas are often relegated to marginal areas of low potential for human conversion at the time at which they are defined (Joppa & Pfaff, 2009). This raises the issue that conservation-targeted areas may in several instances be at low risk of anthropogenic disturbance even without protection. More importantly, from an ecological perspective, several protected areas may be defined despite strong knowledge gaps in the ecological and social needs of considered species (home range, nutrient availability, forage quality, social group composition). The issue is a vicious one: species long relegated to suboptimal habitats due to range contraction (i.e. refugee species), may superficially appear in a natural state, leading to fallacious reasoning in management schemes where populations are kept confined in protected but suboptimal habitat. Scaled-up to the metapopulation level, the occurrence of populations in suboptimal habitats could lead to source-sink dynamics if connectivity between populations is maintained. However, where migration between populations is prevented, refugee populations may be at greater risk of extinction and/or contemporary evolution may render them less capable of coping with environmental changes should they no longer be restricted to marginal habitat (Stockwell, Hendry, & Kinnison, 2003). One highly disturbing thought is that biological ecosystems may be perceived as being in “normal” or “baseline” states by humans, for loss of experience of their past conditions or loss of optimal habitat for comparison (the shifting baseline syndrome; Pauly, 1995; Papworth, Rist, Coad, & Milner-Gulland, 2009). Shifting baselines is a critical problem for conservation. Identifying populations suffering from suboptimal conditions can only be done by going from the individual to the population level, then meta-population scale, to identify correlates of individual health affecting population growth that may differ between populations managed in different habitats. Although challenging, these multi-level studies are needed to insure conservation plans are well informed in terms of habitat suitability for targeted species. This is where macrophysiology (Chown & Gaston, 2016) comes into play.

In a new study, Lea et al. (2018) use a macrophysiology approach to identify potential causes of poor population growth in a vulnerable species, the Cape mountain zebra (Equus zebra zebra) (Ripple et al., 2015). Macrophysiology is the investigation of physiological trait variations over large geographical and temporal scales and the ecological implications of these variations (Chown, Gaston, & Robinson, 2004). It allows identifying physiological markers of individual health or stress related to differential population growth rates in different habitats. After a major population crash of Cape mountain zebras during the 20–21st centuries, three relict populations have recovered well (from <80 to >4,700 individuals) owing to efficient management actions (Hrabar & Kerley, 2013). Nonetheless, in addition to concerns about genetic variation (inbreeding depression) due to small population sizes (Frankham, 1996, 2005), recent analyses of habitat quality (grass abundance, nutrient content and the availability of palatable items) indicate that several populations of this species are managed in potentially suboptimal habitats leading to poor population growth. This has led to a call for identifying
the Cape mountain zebra as a partial refugee species (Lea, Kerley, Hrabar, Barry, & Shultz, 2016).

Lea et al. (2018) use non-invasive measurements of fecal glucocorticoids and fecal androgens across seven South African conservation reserves combined with knowledge on habitat (palatable grass abundance, microclimate) and social group composition (size and sex ratio) within each reserve to explore potential causes of uneven performance of Cape mountain zebra populations across reserves. They show that zebra baseline stress levels (fecal glucocorticoids) are generally more elevated in habitats with low grass abundance and are negatively associated with female fecundity and long-term population growth across habitats. Further, they show that stallion androgen concentrations are higher in small male-biased populations, and negatively associated with female fecundity.

Lea et al.'s study (2018) is important because it convincingly demonstrates how a non-invasive macrophysiological approach can be used at a metapopulation scale to evaluate on-going conservation strategies. Although the exact causes relating higher androgen levels in males to low female fecundity and poor population performance in the Cape mountain zebra remain to be determined (e.g. increased male aggression and female harassment; Rankin & Kokko, 2007), two probable causes are identified: (1) chronic stress related to poor nutrition and availability of palatable grass items in some conservation reserves, and (2) demographic sex-ratio imbalance in some populations.

The study highlights how the combination of bottom-up and top-down approaches may allow seeing the forest through the trees in a metapopulation thought to be managed in suitable habitat and social conditions, yet where several subpopulations are chronically stressed and performing poorly. The same research group is now extending this approach to other species of concern (black rhinoceroses, Diceros bicornis, and Grevy’s zebra, Equus grevyi) (Ripple et al., 2015) multiplying macrophysiological markers of individual health to predict future population viability and the efficiency of management interventions. Such an approach is urgently needed across conservation efforts: African herbivores are unlikely to be alone in this situation.

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REFERENCES